

FIELD MEASUREMENT OF THE MAGNET PROTOTYPES FOR THE VSX PROJECT

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Abstract

Prototypes of the dipole and the fast steering magnet for the VSX project have been fabricated and measured. The field mapping and the end-shim correction were carried out for the dipole, and the frequency response was tested up to 2 kHz for the fast steering. The design of the magnets and measured results are presented.

1 INTRODUCTION

The University of Tokyo has been promoting a project to construct a VUV and Soft X-ray (SX) synchrotron radiation facility in a new campus of the university, Kashiwa campus. The project, which is called "VSX project", is composed of two phases. The first is to construct a 1.0 GeV racetrack ring which has an emittance of 0.7 nm-rad, a circumference of about 230 m and two 30 m long straight sections for insertion devices [1]. It can reach an emittance of diffraction limit and can provide extremely high-brilliance radiation more than 10^{20} [photons/sec/mm²/mrad²/0.1% b.w.] in the region between 100 eV and 1 keV. The second is to construct a 2.0 GeV ring, which has a circumference of 388 m, an emittance of 5 nm-rad and 16 long straight sections [2]. High-brilliance synchrotron radiation over a wide range from VUV and SX can be generated by various kinds of insertion devices.

We have been carrying out the design study and R&D's of the magnet system for both the 1.0 GeV and 2.0 GeV rings. Detailed design of main and corrector magnets for these rings has been almost completed. For the 1.0 GeV ring, prototypes of the dipole, quadrupole and fast steering are being fabricated now. The quadrupole will be delivered to ISSP in this May and the dipole and steering in October. For the 2.0 GeV ring, the dipole, quadrupole, sextupole and fast steering prototypes have been already fabricated by Mitsubishi Electric Corporation, and their field measurements are well under way at ISSP. Some results of the dipole, quadrupole and sextupole measurement have been reported in elsewhere [3,4].

In this paper, we present recent progress of the magnetic measurement of the dipole and the fast steering prototypes for the 2.0 GeV ring. The measurement is being carried out using a computer-controlled 3D mapping

system with a Hall probe unit (SERIES-9900 gaussmeter, F. W. BELL). For the dipole measurement, an NMR system (PT2025, METROLAB) is also used to obtain the absolute field strength and to calibrate the Hall probe unit.

2 DIPOLE MAGNET

Figure 1 shows the end view of the dipole prototype. The magnet core has C-type rectangular configuration and is made of forged low-carbon solid-steel. The shape of pole profile has been optimized using the 2D program LINDA to obtain a field uniformity better than 5×10^{-4} over a horizontal region of ± 40 mm. The main parameters of the dipole are listed in Table 1.

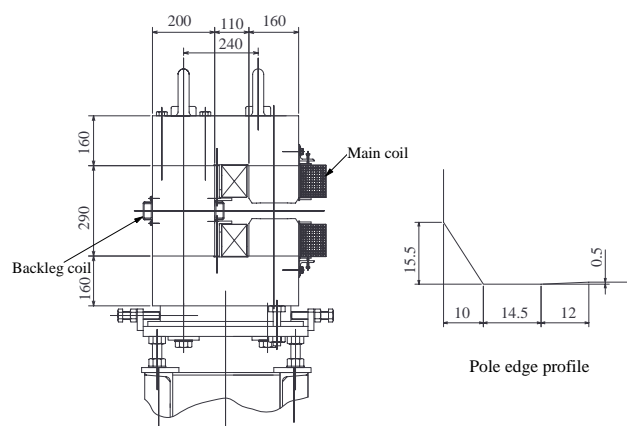


Figure 1: End view of the dipole prototype

Figure 2 shows the measured longitudinal field distribution along the design orbit. The excited field strength at the center of the magnet is 1.006 T. The effective length, defined as the field integral along the design orbit divided by the field at the magnet center, was calculated to be 1364.0 mm.

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Table 1: The parameters of the dipole prototype

| | |
|------------------------|-------------|
| Bending angle | 11.25° |
| Bending radius | 6.626 m |
| Gap height | 50 mm |
| Core length | 1.299 m |
| Maximum field strength | 1.26 T |
| Turns / pole | 30 |
| Maximum current | 960 A |
| Conductor size | 16×15-φ9 mm |
| Resistance | 21 mΩ |
| Water flow | 37.8 l/min |

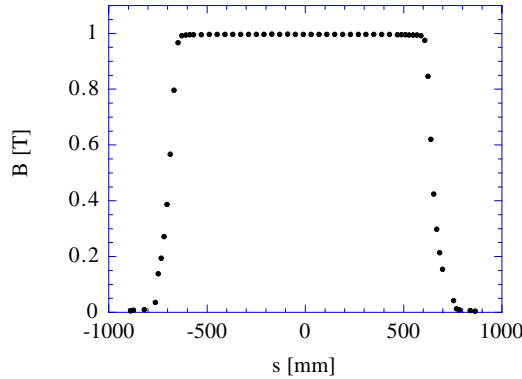


Figure 2: Longitudinal field distribution along the design orbit

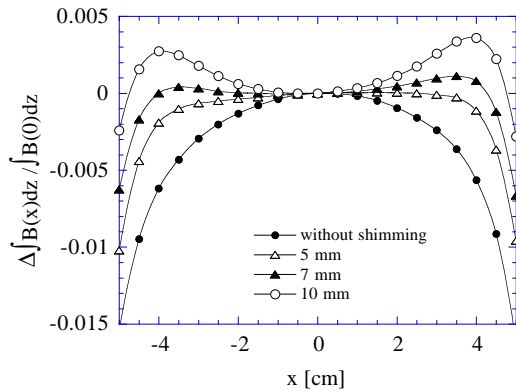


Figure 3: Integrated field profile

Near the magnet end, the sextupole component becomes relatively larger and it makes worse the horizontal field uniformity. In order to reduce the sextupole component, the end correction was carried out by shimming the magnet pole ends. The pieces of the end-shim are pure-iron plates of 25 mm × 139 mm, and 2 mm or 5 mm thick. Figure 3 shows the integrated field uniformity for various thickness of end-shimming. Each integrated field

is calculated from mapping data along the longitudinal (z-axis) direction between $z = 450$ mm and $z = 700$ mm ($z = 650$ mm is the position of the magnet end). This figure implies the most proper thickness is about 6 mm, by which the integrated field uniformity better than 5×10^{-4} is obtained.

3 FAST STEERING MAGNET

The prototype of fast steering magnet is shown in Fig. 4. The steering has an aperture of 151 mm (width) × 46 mm (height) and provides both horizontal and vertical fields. The magnet core is composed of four glued stacks of 0.5 mm-thick silicon-steel lamination. The main parameters of the fast steering are listed in Table 2.

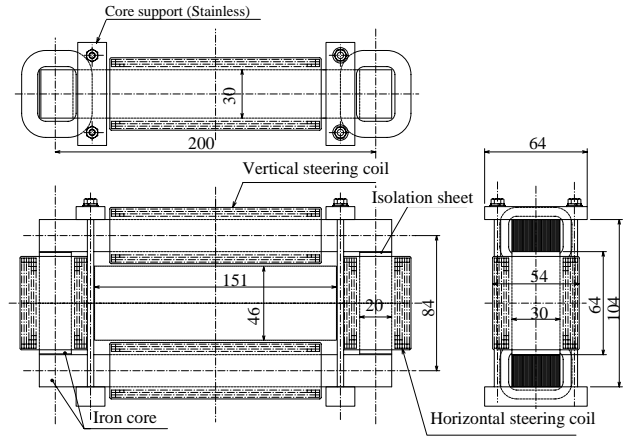


Figure 4: Fast steering prototype

Table 2: The parameters of the fast steering magnet

| | (Vertical steering) | (Horizontal steering) |
|------------------|---------------------|-----------------------|
| Deflection angle | 0.09 mrad | 0.1 mrad |
| Magnet gap | 180 mm | 64 mm |
| Turns / coil | 140 | 120 |
| Maximum current | 5 A | 5 A |
| Coil resistance | 0.25 mΩ | 0.24 mΩ |
| Coil inductance | 7 mH | 8 mH |
| Frequency range | DC ~ 100 Hz | DC ~ 100 Hz |

The fast steering is expected to operate in a frequency range up to 100 Hz. We measured the frequency response of the steering using a dynamic signal analyzer (HP35670A). A swept sine signal from the analyzer was fed into a bipolar AC power supply (IPM-BP series, IDX). The frequency response of the output current of the power supply or the signal of the Hall probe was measured.

Figures 5 and 6 show the Bode diagram of the horizontal and vertical steerings, respectively. The data were measured with the output signal of the Hall probe

put on the position of steering center. The output current of the power supply was set to be 800 mA peak-to-peak, that is a maximum current required for the fast orbit feedback system. A 1 m long vacuum chamber made of aluminum was inserted into the aperture of the steering magnet to examine the effect of eddy current induced on the chamber. The chamber has the same cross section as the beam duct of straight section of the VSX 2.0 GeV ring [5]. As shown in these figures, the steering magnet itself has a good frequency response up to 1 kHz for both the horizontal and vertical directions. Field attenuation due to the effect of eddy current on the vacuum chamber is not very serious in the frequency range up to 100 Hz.

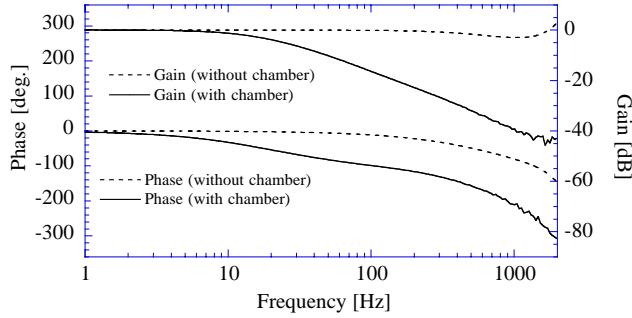


Figure 5: Frequency response of the horizontal steering field

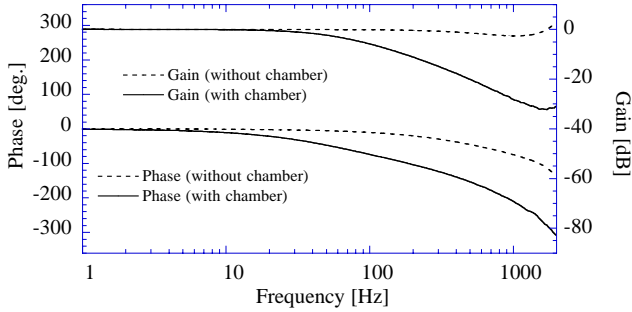


Figure 6: Frequency response of the vertical steering field

In the measurement of Figs. 5 and 6, the data of the vertical steering was taken when the horizontal excitation switched off and vice versa. If both the steerings are excited in the same time, that is the actual situation of feedback operation, the interference between the two steerings may occur due to mutual inductance of the coils. Thus the frequency response should be measured with both of them are switched on. Two AC bipolar power supplies were used in the measurement and driven by the identical signal from the signal analyzer. Figure 7 shows the measured Bode diagram of the power supply output current for vertical steering when the horizontal steering switched

on. The driving current was 800 mA peak-to-peak. The data without horizontal steering is also shown in this figure. There is no significant difference between them. It indicates that the magnetic field is given by a linear combination of the horizontal and vertical steering fields. In fact, even when both the steerings are switched on, the frequency response measured with the Hall probe well agrees with the data in Figs. 5 and 6. It means that independent feedback operation in the horizontal and vertical directions is possible using these steering magnets.

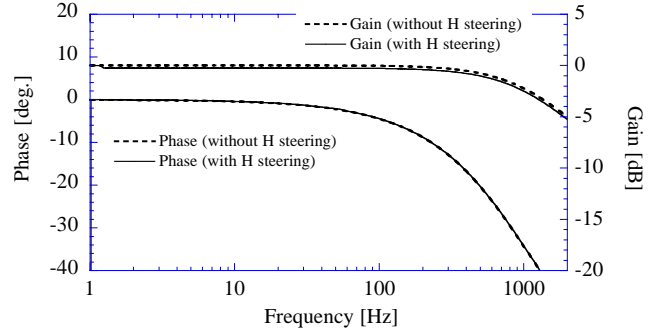


Figure 7: Frequency response of the output current monitor of the vertical steering

4 REFERENCES

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